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Comparative Study of Production Oil from Avocado Apple (*Persea americana*) Using Steam Distillation and Extraction

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ABSTRACT

This work compared the production of oil from the pericarps (peels) of avocado apple using steam distillation and extraction (direct and indirect leaching) with respect to the yields. An improvised steam distillation set-up was used at three different steam heating rates. It entailed the comminution of the sample material suspended on a grid (perforated metal plate) 90mm above the water level and the application of steam through the material. The steam percolated the material and subsequently vaporized the oils from the interlocking matrix of the molecular-atomic units of the avocado pericarps. Variations in time and volume of water used to generate the steam for the process are as follows: 30, 60, 90 and 120minutes and 1000ml, 1250ml and 1500ml respectively. In contrast, leaching method (direct and indirect extraction) using two different solvents namely n-hexane and anhydrous ethanol were used. The extraction was carried out at different particle sizes, times, and the boiling points of the solvents. These were as follows: 0.75mm, 1.00mm, 1.59mm and 2.00mm; 30, 60 90 and 120minutes; 60^oC and 78^oC for n-hexane and anhydrous ethanol respectively. The active principles (oils) from both methods were processed by to produce high quality refined oil. Finally, the crude and refined oils were characterized to determine their suitability for industrial applications. The results from the steam distillation revealed that the heating rate of 2.57ml/min (moderate) gave the maximum oil yield of 59.8% while the results from leaching (direct and indirect extraction) method at a similar extraction time (120minutes), particle size (0.75mm), gave optimum oil yields of 21.2% and 23.9% for indirect and direct leaching respectively using n-hexane, 35.9% and 42.0% for indirect and direct leaching using anhydrous ethanol respectively. The physicochemical analysis of the refined oil showed that the oil has saponification value of 196.4, acid value of 5.653, iodine value of 67.7, free fatty acid value of 0.0872, peroxide value of 67.1.27, specific gravity of 0.90261, viscosity of 181.180cp and refractive index of 1,600. From the results of both methods of production, it is apparent that steam distillation gave the highest yield (59.8%) of oils than leaching (42.0%). The properties of the present oils are in conformity with the international standard^{1, 2} and as such, are potential substitutes for the most oils used for cosmetics and pharmaceutical drugs production.

Keywords: Comparative study, steam distillation, leaching (direct and indirect extraction), Avocado's pericarps.

INTRODUCTION

Avocado apple (*persea americana*) variously known as the avocado, avocado pear, alligator pear, ahucatl or agvacate, is a fruit rich in proteins, fats and oils, and low in sugar³. The total food value is high; providing nearly twice the energy of an equivalent weight of meat. It also contains abundance of several vitamins such as A, B, C, D and E. Generally, the fruits composition by weight is about 65% mesocarp (flesh), 20% endocarp (seed) and 15% pericarp (peels). In addition to the oil, the avocado contains a small amount of about 1.5% weight of oil of unsaponifiable matter, as a distinct fraction, which by itself is a very valuable component useful in many creams and medicated ointments⁴. Three different species have been identified⁵ and all the three species are largely cultivated and produced to varying degrees in the tropical rainforest and savannah belts of Nigeria. However, with the abundant production of avocado apple, in Nigeria, 15% of avocado apple (pericarp/peels) is discarded as waste which ought to have been a potential source for the production of oil for industrial applications^{6,7} especially now that the fruit's pericarp has been reported to have antiviral, antibiotic and insecticidal properties⁸ and can be employed as a vermifuge and remedy for dysentery and in the production of cosmetics.

In view of the above reasoning, the present work targeted the optimal means of obtaining the oil from the apple's pericarps which otherwise was discarded as a waste.

The methods of production of oil from the avocado apples pericarp are as varied as the species [9-12]. Frequently, leaching is used for the extraction of the oil from the avocado's apple and less of steam distillation.

Steam distillation is the process that involves the use of steam to percolate and vaporize out the oil from the plant material or sample with the subsequent condensation of steam and oil prior to their separation using a settling tank, separating funnel or any similar vessel [13,14]. Three different methods of steam distillation are practiced [15, 16, 17]. In the first method, vessel containing water and the sample material are heated by a direct flame and the water vapour and volatile oil are recovered through a condenser. In the second method, the sample material is suspended on a grid above the water level and steam from a second vessel is introduced under the grid. The volatiles are condensed and the oil is separated; and in the third process, the vessel containing the sample material on a grid is heated to prevent condensation of steam so that dry distillation is attained. A necessary condition for the application of steam distillation is that the desired product (oil) must be practically immiscible with water [13,14,18]. The condition that the product desired is not soluble in water means that the distillate will form two layers on condensation from which the product desired can be taken off as one layer and the water as the other layer [19, 20].

Several methods have been developed for the extraction of oils from fruits and other oil-bearing plant materials [21, 22, 23]. One of such involved the use of chemical solvents that are later removed during the final stages of production. This is the solvent extraction method. Solvent extraction (leaching) involves separating the components or constituents of the mixture based on their chemical differences rather than differences in physical properties. It depends on the selective dissolution of one or more liquid constituents of the mixture into a suitable immiscible liquid solvent. The basic principle behind the extraction involved contacting of a solution with

another solvent that is immiscible with it. The solvent is also soluble with a specific solute contained in the solution²⁴. Two phases are formed after the addition of the solvent due to the differences in densities. The solvent is chosen so that the solute in the solution has more affinity towards the solvent. This is based on the concept of an equilibrium or ideal stage which is the stage from which the resultant solution is of the same composition as the solution adhering to the solids leaving the stage^{25,24}. The two phases may be solid and liquid, immiscible liquid phases, or solid and gas.

Aim and Objective of the Study

The aim of the study was to find possible uses of the avocado apples pericarps/peels that hitherto had been discarded as wastes. Specifically, the work was aimed at comparing the yield of oil produced from the pericarps of the avocado apple using steam distillation from an improvised steam distillation set-up and extraction methods; thus identifying the method that gave the highest yields.

MATERIALS AND METHODS

The experimental procedures involved the procurement of materials and equipment; pretreatment of avocado apple and peels (pericarp); steam distillation and extraction of the oil from the avocado's pericarp; characterization of both the crude and refined oil.

In this work, only the unconventional materials and major equipment set-up used in the experiment are given in Tables 1 and 2 respectively.

Table 1: List of Materials Used for the Experiment

Materials	Source	Research code name	Comments
Avocado Apple	Obollo-Afor Market, Nsukka, Enugu – Nigeria	AVOA	Fresh greenish to very dark green in colour Amber, dark brown to appear black in colour
Avocado Peel/Pericarp	Avocado Apple	AVOP	Bp 60°C n-hexane >>>99% BDH (ANALAR) Highly flammable volatile liquid
N – Hexane	WR international Ltd Poole, BH15 1TD, England	UN 1208 (N – H)	99.7–100% Ethanol, bp 78°C analytical grade
Anhydrous Ethanol	BDH Chemicals Poole, England	UN 1170 (ABS)	

Procurement and Pretreatment of Avocado Apple and Peels (Pericarp)

The avocado apple was sourced locally from Obollo-Afor market, Nsukka, in Enugu state of Nigeria. The fruits were thoroughly washed and screened to remove foreign bodies. The pericarp/peel was removed from the mesocarp and the endocarp (seed). The pericarp/peel was dried at ambient temperature (25°C) for five days to eliminate moisture. The dried pericarp was thereafter reduced to particle sizes ranging from 0.75mm to 2.00mm

Table 2: List of Equipment Used for the Experiment

Materials	Source	Model	Comment
Steam Extraction Still	Awal industries, Kaduna	NA	Stainless steel material
Soxhlet Extractor	Pyrex, England	BDB 24	Glass apparatus
Separating Funnels and Settling Tanks	AG, Borosilicate, England	BS2021	Glass apparatus
Connecting Slits	Quickfit, England	DA23	Glass apparatus
Weighing Balance	Ohaus, USA	B300D	Digital display
Measuring Cylinder	Technico, England	BS604	Glass apparatus
Condensers	AG, Borosilicate, England	BS1848	Glass apparatus
Oven	Gallenkamp, England	CE94	Vacuum drier
Stack of Sieves	Chemical, Engineering Laboratory, FUT, Minna	SOS241	Stainless steel
Heating mantle	Electrothermal Britain Everest, China	B300	
	Local, Minna	ANI020	
		LM	Stainless case Ceramic-stainless case Galvanized steel case

Experimental Procedure

Steam distillation of oil from AVOP

Ten (10) grams of AVOP and varying volumes of 1000ml, 1250ml and 1500ml of water for steam generation were used alternatively at slow or low, moderate or medium and fast or high heating rates respectively. 1000ml of water was introduced into the bottom chamber of the still. The chamber was covered with a perforated metal plate in which a white filter cloth was placed. 10g of AVOP was then placed on the filter cloth. This was further covered with white filter cloth. The last perforated metal plate was placed on the top compartment. Finally, the still was made air tight with the last covering to prevent the escape of the steam – oil mixture during heating. The set-up was then connected to a condenser via a pipe fixed at the top of the extraction still where an opening had been made. The delivery tube from the condenser was connected to the separating funnel to receive the mixture of steam and oil on condensation. The set – up was then mounted and connected to three heating sources alternatively for extraction times of 30, 60, 90, 120, 150, and 180 minutes respectively. At the end of the time intervals, the set-up was switched-off and allowed to cool. The water-oil mixture was decanted to separate the oil from the water at the water-oil interface. Thereafter the mass of the AVOP after extraction and drying in an electric oven was recorded. The mass of oil extracted was also recorded.

This procedure was repeated for 1250ml and 1500ml of water with 10g of AVOP at extraction times of 30, 60, 90, 120, 150 and 180 minutes at the three heating rates respectively. The steam-sample ratio, steam and sample utilization and steam supply rate for each extraction times were recorded.

Indirect (Soxhlet) extraction of oil from AVOP

In this process, 10g of AVOP each of particle sizes 0.75mm, 1.00mm, 1.59mm and 2.00mm and two solvents namely n-hexane and anhydrous ethanol were used alternatively in the indirect extraction (leaching) using the soxhlet extractor. 10g of AVOP, 0.75mm particle size, was placed inside a thimble and inserted into the inner tube of the soxhlet extractor. This apparatus was then fitted to a round bottom flask, which contained 200ml of the solvent (n-hexane or anhydrous ethanol). A reflux condenser was also mounted and fitted on the apparatus. The set-up was held tight with a retort stand and then placed on a heating mantle that was switched-on for extraction times of 30, 60, 90, 120, 150 and 180 minutes at the boiling point of the solvent (n-hexane, 60⁰C or anhydrous ethanol, 78⁰C). The vapour passed up through the tube, condensed by the condenser and the condensed solvent falls into the thimble and slowly fills the body of the soxhlet. When the solvent reached the top of the tube, it siphoned over into the flask and thus removed the portion of the sample that has been extracted in the thimble. The process repeated itself automatically for the extraction times and the apparatus was dismantled. The mass of AVOP after extraction and drying in an electric oven was weighed and the weight recorded.

These procedures were repeated for particle sizes 1.00mm, 1.59mm and 2.00mm using fresh samples of the same mass (10g) and the same solvent (n-hexane or anhydrous ethanol) at the boiling point of the solvent, (60⁰C for n-hexane, or 78⁰C for anhydrous ethanol) for each samples at extraction times of 30, 60, 90, 120, 150 and minutes respectively for each particle size and solvent.

The solvent recovery process involved using the same soxhlet extractor. The mixture of solvent and oil (also called miscella) was heated in the flask. On constant heating, the solvent evaporated and thereafter condensed in the thimble chamber. The solvent was collected before it siphoned back into the flask. The extracted oil was then recovered and the mass recorded.

Direct Extraction of Oil from AVOP

In this process, 10g of AVOP each of particle size 0.75mm, 1.00mm 1.59mm and 2.00mm and two solvents namely n-hexane and anhydrous ethanol were used alternatively in the direct extraction (leaching) of oil from AVOP. 10g of AVOP; 0.75mm particle size, was measured into a round bottom flask which contained 200ml of the solvent (n-hexane or anhydrous ethanol). The mixture was vigorously agitated by swirling the flask. A reflux condenser was mounted and fitted onto the conical flask. The condenser was then connected to a tap water source. The vent of the flask was made air-tight to prevent the escape of the evaporating solvent. The set-up was held tight with a retort stand and the mixture placed on an electric heater and the thermostat adjusted to maintain a constant heating rate at the boiling point of the solvent (n-hexane, 60⁰C and anhydrous ethanol, 78⁰C). The mixture was allowed to boil for the extraction times of 30, 60, 90, 120, 150 and 180 minutes respectively. The vapour from the boiling solvent was made to condense and return to the mixture by means of a reflux condenser which was mounted on the flask through which water was constantly flowing. After the extraction had been completed, the heater was switched-off and the solvent decanted and filtered. The raffinate was weighed and its weight recorded after drying in an electric oven.

These procedures were repeated for particles sizes 1.00mm, 1.59mm and 2.00mm using fresh sample of the same mass (10g) and the same solvent (n-hexane or anhydrous ethanol) at the

boiling point of the solvent (60⁰C for n-hexane or 78⁰C) for each samples at extraction times of 30, 60, 90, and 120, 150 and 180 minutes respectively for each particle size and solvent.

Solvent recovery process was further carried-out on the extract phase to obtain the oil extract (active principle). This involved the use of the soxhlet extractor. On constant heating, the solvent evaporated and thereafter condensed in the thimble chamber. The solvent was collected before it siphoned back into the flask. The extracted oil was then recovered and its mass recorded.

Subsequently, the crude AVOP oil was refined with activated clay (bleaching earth) which was previously sieved to 70-5 microns. 0.1% by weight of the clay was added to 10g of the oil sample. The mixture was heated to a constant temperature of 100⁰C with stirring for 30 minutes. The oil was then filtered at the same temperature and the filtrate characterized, in order to determine its physiochemical properties and have its suitability for industrial applications.

Characterization of the Crude and Refined Oils

The crude and refined oil samples were subjected to various physicochemical analysis (ISO/TR 21092, ISO 212, ISO/TR 210, and AOCS) to determine its properties such as saponification value, iodine value, peroxide value, free fatty acid value, acid value, specific gravity, refractive index and viscosity.

RESULTS AND DISCUSSION

The comparative yields of oils from steam distillation and leaching of avocado's pericarp at the optimized thermodynamic conditions and varying particle sizes of the avocado's pericarp are given in Tables 3.0, 4.0 and 5.0. The physicochemical prophecies of both crude and refined oils are given in Tables 6.0 and 7.0

In Table 3.0, comparison of oil yields from steam distillation and extraction at varying particle sizes and 120 minutes extraction time is presented. At the extraction time, the maximum oil yield was 59.8% which was from particle size of 2.00mm. The production method for this oil yield was steam distillation at moderate steam heating rate. From the results in table 3.0, it was revealed that the optimal oil yields of 42.0% and 23.9% was achieved from direct extraction (leaching) at the boiling points of anhydrous ethanol (78⁰C) and n-hexane (60⁰C) respectively. Similarly indirect extraction (leaching) gave optimal oil yields of 35.9% and 21.2% for anhydrous ethanol and n-hexane at their boiling point respectively. The yields of oils for both the direct and indirect extraction (leaching) were achieved from particle size of 0.75mm at the extraction time of 120 minutes (Table 3.0).

In Table 4.0, comparison of maximum (highest) oil yields from steam distillation and extraction (direct and indirect leaching) at optimal particle size and varying extraction time are presented. From the table, the maximum oil yield at extraction time of 30 minutes was 37.8%. This was from particle size 0.75mm and direct extraction (leaching) using anhydrous ethanol at its boiling point of 78⁰C. From Table 4.0, at the extraction time of 60 minutes, and particle size of 0.75mm, the highest oil yield from the result was 40.0%. The production method was direct extraction (leaching) using anhydrous ethanol. Similarly, at the extraction time of 90 minutes, the optimal oil yield was 50.2%. This was achieved from steam distillation method at moderate steam

heating rate and particle size of 2.00mm. At the highest extraction time (120 minutes), Table 4.0 revealed that the maximum oil yield was 59.8% which represented the moderate steam heating rate. Table 4.0 thus showed the effects of particle size, solvents and extraction time on the yields of oils. The table revealed that at higher extraction times, higher oil yields were achieved which conform to literature (Table 4.0).

Table 3.0: Comparison of Oil Yields from Steam Distillation and Extraction at Varying Particle Size and 120 minutes Extraction Time

Production Method	Mass of AVOP (g)	Solvent	Time (mins)	Particle Size (mm)	Mass of AVOP after extraction and drying (g)	Mass of oil extraction (g)	% Yield
Steamed distillation (low steam rate)	10	Steam	120	2.00	6.47	3.53	35.3
	10	“	120	2.00	6.26	3.74	37.4
Steam distillation (high steam rate)	10	“	120	2.00	6.13	3.87	38.7
	10	Steam	120	2.00	6.20	3.80	38.0
Steam distillation (moderate steam rate)	10	“	120	2.00	6.04	3.96	39.6
	10	“	120	2.00	6.25	3.75	37.5
Indirect extraction (leaching)	10	Steam	120	2.00	4.02	5.98	59.8
	10	“	120	2.00	5.28	4.72	47.2
Indirect extraction (leaching)	10	“	120	2.00	4.12	5.88	58.5
	10	n-hexane	120	0.75	7.88	2.12	21.2
Indirect extraction (leaching)	10	“	120	1.00	8.09	1.91	19.1
	10	“	120	1.59	8.21	1.79	17.9
Indirect extraction (leaching)	10	“	120	2.00	8.29	1.71	17.1
	10	Anhydrous Ethanol	120	0.75	6.41	3.59	35.9
Direct extraction (leaching)	10	“	120	1.00	6.60	3.40	34.0
	10	“	120	1.59	6.81	3.19	31.9
Direct extraction (leaching)	10	“	120	2.00	6.85	3.15	31.5
	10	n-hexane	120	0.75	7.61	2.39	23.9
Direct extraction (leaching)	10	“	120	1.00	7.79	2.21	22.1
	10	“	120	1.59	8.00	2.00	20.0
Direct extraction (leaching)	10	“	120	2.00	8.03	1.97	19.7
	10	Anhydrous Ethanol	120	0.75	5.80	4.20	42.0
Direct extraction (leaching)	10	“	120	1.00	6.29	3.71	37.1
	10	“	120	1.59	9.42	3.58	35.8
Direct extraction (leaching)	10	“	120	2.00	6.52	3.48	34.8

In Table 5.0, comparison of maximum (highest) oil yield from steam distillation and extraction (direct and indirect leaching) at optimal particle sizes and 120 minutes extraction times are presented. From the results in the table, the maximum oil yield at the extraction time was 59.8% from steam distillation at moderate steam heating rate. The particle size for the optimal oil yield was 2.00mm which was the optimal particle size for steam distillation method. Table 5.0, also shows the effect of particle sizes, solvent types and extraction time on the yields of oils using the production methods of steam distillation and extraction (Table 5.0).

Table 4.0: Comparison of Maximum (Highest) Oil Yields from Steam Distillation and Leaching (Direct and Indirect) at Optimal Particle Size and Varying Extraction Times

Production Method	Mass of AVOP (g)	Solvent	Time (mins)	Particle Size (mm)	Mass of AVOP after extraction and drying (g)	Mass of oil extraction (g)	% Yield
Steam distillation (low steam rate)	10	Steam	30	2.00	7.62	2.38	23.8
Steam distillation (high steam rate)	10	Steam	30	2.00	7.47	2.53	25.3
Steam distillation (moderate steam rate)	10	Steam	30	2.00	7.20	2.80	28.0
Indirect extraction (leaching)	10	n-hexane	30	0.75	8.54	1.46	14.6
Indirect extraction (leaching)	10	Anhydrous ethanol	30	0.75	6.79	3.21	32.1
Direct extraction (leaching)	10	n-hexane	30	0.75	8.02	1.98	19.8
Direct extraction (leaching)	10	Anhydrous ethanol	30	0.75	6.22	3.78	37.8
Steam distillation (low steam rate)	10	steam	60	2.00	7.12	2.88	28.8
Steam distillation (High steam rate)	10	steam	60	2.00	7.11	2.89	28.9
Steam distillation (moderate steam rate)	10	steam	60	2.00	6.20	3.80	38.0
Indirect extraction (leaching)	10	n-hexane	60	0.75	8.14	1.86	18.6
Indirect extraction (leaching)	10	Anhydrous ethanol	60	0.75	6.60	3.40	34.0
Direct extraction (leaching)	10	n-hexane	60	0.75	7.87	2.13	21.3
Direct extraction (leaching)	10	steam	90	2.00	6.00	4.00	40.0
Steam distillation (low steam rate)	10	steam	90	2.00	6.84	3.14	34.4
Steam distillation (high steam rate)	10	steam	90	2.00	6.52	3.48	34.8
Steam distillation (moderate steam rate)	10	steam	120	2.00	4.98	5.02	50.2
Indirect extraction (leaching)	10	n-hexane	90	0.75	7.98	2.02	20.2
Indirect extraction (leaching)	10	Anhydrous ethanol	90	0.75	6.50	3.50	35.0
Direct extraction (leaching)	10	n-hexane	90	0.75	7.71	2.29	22.9
Direct extraction (Leaching)	10	Anhydrous ethanol	90	0.75	5.86	1.14	41.4
Steam distillation (low steam rate)	10	steam	120	2.00	6.13	3.87	38.7
Steam distillation (high steam rate)	10	steam	120	2.00	6.29	3.96	39.6
Steam distillation (moderate steam rate)	10	steam	120	2.00	4.02	5.98	59.8
Indirect extraction (leaching)	10	n-hexane	120	0.75	6.52	2.12	21.2
Indirect extraction (leaching)	10	anhydrous ethanol	120	0.75	6.41	3.59	35.9
Direct extraction (leaching)	10	n-hexane	120	0.75	7.61	2.39	23.9
Direct extraction (leaching)	10	anhydrous ethanol	120	0.75	5.80	4.20	42.0

Table 5.0: Comparison of Maximum (Highest) Oil Yields from Steam Distillation and Leaching (Direct and Indirect) at Varying Particle Size and 120 minutes Extraction Time

Production Method	Mass of AVOP (g)	Solvent	Time (mins)	Particle Size (mm)	Mass of AVOP after extraction and drying (g)	Mass of oil extraction (g)	% Yield
Steam distillation (low steam rate)	10	Steam	120	2.00	6.13	3.87	38.7
Steam distillation (high steam rate)	10	Steam	120	2.00	6.04	3.96	39.6
Steam distillation (moderate steam rate)	10	Steam	120	2.00	4.02	5.98	59.8
Indirect extraction (leaching)	10	n-hexane	120	0.75	7.88	2.12	21.2
Indirect extraction (leaching)	10	anhydrous ethanol	120	0.75	6.41	3.59	35.9
Direct extraction (leaching)	10	n-hexane ethanol	120	0.75	7.61	2.39	23.9
Direct extraction (leaching)	10	anhydrous ethanol	120	0.75	5.80	4.20	42.0

Physicochemical Properties of Crude and Refined AVOP Oils.

The physicochemical properties of both the crude and refined oils are given in Tables 6.0 and 7.0 respectively.

Table 6.0 gives the results of the analysis on the crude AVOP oil samples, that is, the physicochemical properties. From the table, the values of properties fall within the range of values for oils used in similar applications with reference to organization such as the international organization for standardization (ISO) and the American oil chemists' society (AOCS) standards (Table 6.0).

Table 6.0: Physicochemical Properties of the Crude AVOP Oil

Properties	Value
Saponification value, (ml/kg)	198
Iodine value, (from GLC)(mg/l)	72.4
Peroxide value, (meq/kg fat)	3.07
Free fatty Acid value, (as Oleic)(%)	0.08729
Acid value, (ml/kg)	6.8943
Specific gravity, (@25 ^o C)	0.9162
Refractive index	1,465
Viscosity, (cp)	180.43
Boiling Point, (^o C)	89-90

Table 7.0 gives the values of the physicochemical properties of the refined AVOP oil which are most commonly used to establish the identity of oils. Each of the property was chosen to measure specific characteristics of the oil.

From Table 6.0 and 7.0, the properties of the oil such as saponification values, iodine value, peroxide value, free fatty acid value and acid value are mostly used to specify the characteristics

of the oil. The others are empirical in nature though they also give useful guidance in identifying the oil.

Comparison of Tables 6.0 and 7.0 revealed that the difference in saponification value between the crude and refined oils was less than 1.0% (0.81%). This is attributable to the fact that the oil's many natural constituents are still present and hence, little lipase activity.

Table 7.0: Physicochemical Properties of the Refined AVOP Oil

Properties	Value
Saponification value, (ml/kg)	196.4
Iodine value, (from GLC)(mg/l)	67.7
Peroxide value, (meq/kg fat)	1.27
Free fatty Acid value, (as Oleic) (%)	0.0872
Acid value, (ml/kg)	5.653
Specific gravity, (@25 ⁰ C)	0.90261
Refractive index	1,600
Viscosity (cp)	181.180
Boiling Point (⁰ C)	89

Also, from the tables, a 65% level decrease in iodine value between the crude and refined oils implied that less amount of hydrogen would be required in converting the unsaturated components of the oil into saturated oil for industrial use.

Similarly, the lower peroxide value (58.63%) of the refined oil implied that the oil cannot be early decomposed and neither can it become rancid as a result of the presence of triglyceride esters of the oil to form peroxide when compared to the crude oil.

An acid value of less than 10 enhances the stability of most oils and both values fall within this range. Thus, the refining quality of the oil is enhanced.

The low value of the free fatty acid values for both the crude and refined oils implied that the oil contains acid that are uncombined with glycerol and thus, do not easily decompose nor become rancid; indicating little lipase activity.

Other constituents of the crude and refined oil include its richness in vitamins A, B, G, and E. It has digestibility coefficient of 93.8% but can't be used extensively as edible oil due to its cost; its amino acid content is as follows: palmitic, 7.0, stearic, 1.0, oleic, 79.0 and linoleic, 13.0. The oil has excellent keeping quality staying as long as possible with only slight rancidity and can be used as hair-dressing, making facial creams, hand lotions and fine soap. It has a high lipid content of both saturated and unsaturated fatty acids in the form of palmitic, stearic, oleic and linoleic in varying compositions and percentages. However, the oil is predominantly monounsaturated and is low in saturates. It has added benefit in that it contains beta-sitosterol in significant amounts (0.5- 1.0) and thus its consumption is recommended especially for the elderly in alleviating the symptoms of benign prostatic hypertrophy.

CONCLUSION

The conclusions emerging from this research work includes the following.

1. A high quality oil could be obtained from the pericarp of the avocado apple which hitherto was discarded as waste.
2. A steam distillation process at moderate steam heating rate gave the highest oil yield of 59.8% from the pericarp at extraction time of 120 minutes.
3. The effect of particle size variations was not significant on the steam distillation process as smaller particle sizes (<2.00mm) formed lumps on percolation of the steam through them making extraction difficult.
4. The rate of extraction was known to proceed favorably with increasing time (both steam distillation and direct and indirect leaching) and decreasing particle sizes (direct and indirect leaching) at the temperature of extraction. The results of this work were supportive of that fact.
5. The yields of oils from indirect and direct leaching using n-hexane and anhydrous ethanol increased progressively with decreased particle size and increasing extraction time at the boiling points of the solvents. Also, the affinity of the sample materials toward either of the solvents used showed that anhydrous ethanol was more useful as the leaching solvent based on the yields of oils obtained than n-hexane for this particular work.
6. The physicochemical properties of both the crude and refined oils from both methods were found comparable with oils of similar structural constituents used for industrial applications.

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